Dear Prof. Dr. Rónadh Cox,

First of all we would like to thank you for taking the effort to provide us with additional feedback on our manuscript with your comment in the open discussion. While a more in-depth response and the updated manuscript will be provided upon receiving the decision of the editor, we would already like to address your primary concerns briefly and point-by-point in this reply.

1. **Area calculation**

   Detailed lavaka areas have been delineated based on high resolution (0.5 m) satellite imagery over the period 2011-2018 and based on 2.4 m resolution historical aerial images (these datasets are described in detail in Brosens *et al.* (2021) and are provided the corresponding FileShare repository). On these previously mapped areas, the area-volume relationships obtained in this manuscript have been applied in order to estimate the lavaka volumes in 1949 and 2010s. We will revise the corresponding sections of the manuscript in order to make sure that this is clearly formulated and that the supplementary raw data are more clearly referred to.

2. **Data of the A-V relationship**

   We regret that it was not indicated clear enough in the manuscript that the supplementary data of this work can be found at the following repository: https://doi.org/10.5281/zenodo.5155317. This is mentioned in the *code and data availability* section, but we will also refer to this in the text to make sure that the reader finds these data. In the repository we provide an excel table containing the original lavaka areas and volumes that were used to establish the area-volume relationship for each of the DEMs. This table also contains the detailed areas of all lavaka (see point 1) and the estimated lavaka volumes based on the established A-V relationships (for TanDEM-X and UAV-SfM) as well as the derived volumetric growth and mobilization rates. In the revised version of the manuscript additional uncertainties that result from both the interpolation and relative elevation error will be added to this table (see also our reply to Purinton (reply 2021) for details on the new uncertainty calculations).

   The area-volume data are shown in Figure 5 in log-transformed form. We will add a figure of the non-log transformed data to the supplementary files. In Figure 5 no R^2 or other measure of fit is indicated because we use this figure to illustrate that issues are present for the smallest lavaka for the TanDEM-X dataset. The area-volume data that are used to establish the area-volume relationship are displayed in Figure 6b, where the R^2 and the coefficients of the fitted linear relationship are displayed. The uncertainties related to these fitted coefficients are indicated in Equation (3) and (4) and are further discussed and taken into account in our subsequent volumetric growth and mobilization rates calculations (line 215-220).

   The topographic data that are presented in the FigShare repository and that were used to verify the relationships by Cox (reply 2021) are based on the TanDEM-X DEM. While we agree that the depth of the lavaka can probably be approached by the relief, this will result in additional scatter. The observation that the linear fit fails at smaller volumes is in agreement with the data that we show in the manuscript: the TanDEM-X DEM is too coarse to accurately assess the volumes of the smaller lavaka (Figure 5). Our proposed breakpoint analysis allows to identify the point below which these TanDEM-X derived volumes suffer from errors. As we further discuss in lines 346 –

355 the impact of not using the smallest lavaka to establish this area-volume relationship on the final mobilization rates is likely minimal, as these lavaka contribute 1.1 to 21.6% of the total mobilized sediment.

We did not try to fit the A-V relationships for the different study areas separately, as we argue that the most robust fit is obtained using all data.

3. Uncertainties on the Area-Volume relationship

We agree that even after the breakpoint-correction relatively large uncertainties apply to the established area-volume relationship. In the current version of the manuscript we considered these uncertainties by running a Monte Carlo analysis where we take into account the uncertainties on the fitted A-V coefficients (line 216-220). Based on the additional uncertainties that we have now calculated for the lavaka volumes, where we take into account both the interpolation and relative elevation error (see reply too Purinton (reply 2021)), these uncertainty envelopes will become bigger. Uncertainties were already calculated for the derived volumetric growth and mobilization rates and are shown in Table 1. We envision to discuss these uncertainties in more detail as this concern was also raised by Purinton (reply 2021) and Frankl (reply 2021).

4. Underlying geomorphology

We agree that lavaka development over time follows different phases. However, in this study we do not consider the specific evolution of lavaka over time.

Based on empirical evidence, we establish a general relationship between lavaka areas and volumes. The geomorphological evolution of growing lavaka (they might indeed become shallower at the final stages) is implicitly embedded in this relationship. We calculate current mobilization rates based on measured area changes over the period 1949-2010s, where we are confident that we can obtain total volumes of eroded sediment with their respective uncertainties over this temporal interval (see also reply to Purinton (reply 2021)).

We agree that more justification is needed for the fact that we derive area-volume relationships as is often done for landslides, as opposed to length-volume relationships which is more typical for gullies. This concern was also shared by Frankl (reply 2021). The main reason to use area instead of length is the specific shape and growth of lavaka, which typically both widen and lengthen as they grow. Given the large variety of lavaka shapes we argue that lavaka areas will be more precise in establishing a correct volume relationship. This rationale will be added in further detail to the revised version of the manuscript. We want to point out that the choice of using an area-volume relationship, which is typically used for landslides, does not imply that the applied bias correction is based on landslide modelling assumptions. The bias correction is a statistical concept to correct for changes in coefficients when transforming fitted coefficients from a linear fit through log-transformed data to coefficients of a power function on non-transformed data (this principle is for example well described for the establishment of suspended sediment rating curves (Ferguson, 1986; Crawford, 1991)).

5. Bulk densities

We agree that bulk densities will be lower for the deeper layers and will use the proposed bulk density of 1.1-1.2 t/m³ as mentioned in the literature for our revised mobilization rate calculations.

6. **Comparison of current mobilization rates with long-term ^{10}Be erosion rates**
   We agree that we should be cautious in comparing long-term ^{10}Be erosion rates derived from river sediments with the calculated current lavaka mobilization rates. Indeed, a large part of this mobilized sediment will be trapped close to the lavaka and will not reach the rivers. The lake infill data that we refer to (Mietton *et al.*, 2005) are, however, also recent infill data (1987-2005) and will only entail the sediment that has reached the lake and is therefore not deposited close to the lavaka. The reported lake sedimentation rate of 20 ton ha^{-1} yr^{-1} is less than half of our obtained mobilization rates over the period 1949-2010s, suggesting that indeed a considerable proportion of the sediment that is mobilized by lavaka will not reach the rivers or lakes. These recent lake sedimentation rates are, however, still almost two orders of magnitude higher than the long-term ^{10}Be erosion rates, which corroborates with a recent increase in erosion rates. We will provide a more thorough discussion on these matters with the necessary precautions and caveats to better frame these results.

We hope that we have clarified most of the concerns raised and are looking forward to further discuss or clarify these matters if needed.

Sincerely,

Liesa Brosens on behalf of the co-authors

References:

Brosens, L., Broothaerts, N., Campforts, B., Jacobs, L., Razanamahandry, V. F., Van Moerbeke, Q., Bouillon, S., Razafimbelo, T., Rafolisy, T. and Govers, G. (2021) 'Under pressure: Rapid lavaka erosion and floodplain sedimentation in central Madagascar', *Science of The Total Environment*, 806, p. 150483. doi: 10.1016/j.scitotenv.2021.150483.

Cox (reply 2021). CC1: Comment on esurf-2021-64 by Rónadh Cox, 19 Oct 2021. https://doi.org/10.5194/esurf-2021-64-CC1

Crawford, C. G. (1991) 'Estimation of suspended-sediment rating curves and mean suspended-sediment loads', *Journal of Hydrology*, 129, pp. 331–348. doi: 10.1016/0022-1694(91)90057-O.

Ferguson, R. I. (1986) 'River Loads Underestimated by Rating Curves', *Water Resources Research*, 22(1), pp. 74–76. doi: 10.1029/WR022i001p00074.

Frankl (reply 2021). RC2: Comment on esurf-2021-64 by Armaury Frankl Oct 2021. https://doi.org/10.5194/esurf-2021-64-RC2

Mietton, M., Leprun, J.-C., Andrianaivoarivony, R., Dubar, M., Erismann, J., Beiner, M., Bonnier, F., Grisori, E., Rafanomezana, J.-P. and Grandjeaw, P. (2005) 'Ancienneté et vitesse d'érosion des lavaka à Madagascar', *Actes des Journées scientifiques du réseau Erosion et GCES de l'AUF*, (1954), pp. 87–94.

Purinton (reply 2021) RC1: Comment on esurf-2021-64 by Benjamin Purinton, 30 Aug 2021.
https://doi.org/10.5194/esurf-2021-64-RC1